CHAPTER 9

Oil Cans and Projectors – Livens, Flame and Gas 1915–18

Perhaps the strangest mortar to emerge during the war was the oil can mortar invented by Captain Livens, RE, which was designed to throw incendiaries rather than high explosive. At the time he conceived the idea, he was in command of the Flammenwerfer Company (which he had commanded since its inception in 1915), one of the Special Companies of the Royal Engineers and was in France to use the flame projectors to silence enemy machine-guns in the Somme offensive. However, he faced a serious problem of range: the weapons could not be fired from the British line because it was too far away from the German trenches for the stream of flame to reach, as the projector only had a range of 110 yd. He hit upon the idea of a simple mortar to throw oil-based incendiaries in bombs rather than project fire out of a nozzle.

The mortar was indeed very simple, so simple in fact as to almost defy logic. Nevertheless, reasoned thought was at the heart of the invention. The oil for the flame projector was stored in 12-gallon drums, made of 1/16-inch thick sheet steel. These were approximately 12 inches in diameter and 20 inches tall. According to Livens 'when the top was removed [it] formed a very simple mortar tube'. Such a tube seemed an unlikely candidate from which to fire mortar rounds since logic suggested that it would not withstand much of a charge before bursting. Nothing ventured, nothing gained, Livens decided to give it a go, setting some drums in the ground at 45°. The projectiles for these unlikely mortars were equally unusual, being made from Army Service Corps 3-gallon round-section drums. These were about 12 in deep and were used for transporting lubricating oil. These were no more than tin cans with soldered bases. The soldered joints were the weakest points and needed to be supported in some way. Livens reasoned that if the force of propulsion could be made to act perpendicularly to the base of the 3-gallon drum, the side wall would be strong enough to keep the bomb in one piece.

For much the same reason, the flat base of the 12-gallon drum mortar tube would be the strongest part of the mortar as it would be supported directly by the ground and the walls would not have to withstand great pressure. To satisfy these two requirements, Livens had some discs of wood cut to a diameter about 1 in less than that of the mortar tube but greater than the diameter of the 3-gallon can. He now had all the components. All he had to do was to see if it would work.

A small charge of a few ounces of black powder was put inside the larger drum and the wooden disc placed on top. The smaller drum, containing 'very inflammable Persian distillate', was then put inside the larger drum. The fuse consisted of streamers of oily sacking tied to the handle of the 3-gallon can which was ignited by the flash of discharge. A trial run showed that the 3-gallon can could be thrown 200 yd and stay in one piece until it hit the ground, when it burst open, spilling its contents which were then ignited by the burning streamers. It was remarkably effective. A few refinements were necessary, however, such as putting blocks on the wooden disc to ensure that the charge was always the same

volume and evenly spread. Livens also decided that it would be wise to put the powder in some sort of waterproof 'cartridge' and experimented with slightly different sizes of disc. It had taken Livens less than a week, from inception to usable weapon.

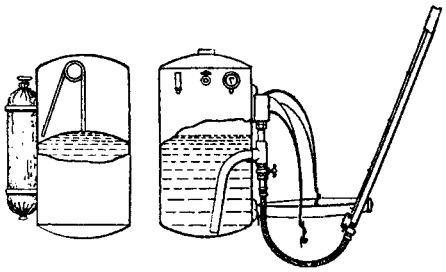
The mortar not only worked but it was simple to use and tube and bomb could be carried by one man, one under each arm. When used in earnest the effect was devastating. A salvo of 100 oil can mortar bombs was in Livens's words 'most impressive, and a considerable area of ground was smothered in burning oil'. He later demonstrated the mortar to the King when he visited France. The oil can mortar was first used against machine-gun positions at La Boiselle on the night of 25 July 1916 as the Australians were attacking Pozières. Livens received orders at 11 p.m. on the preceding day and a dawn reconnaissance of the enemy positions revealed two strong points, each of which 'consisted of ring trenches at the junction of other trenches'. These contained machine-guns with good fields of fire over the area of No Man's Land that the attacking infantry would have to cross.

Another strong point was discovered at the eleventh hour, after the reconnaissance had been completed and this too needed to be dealt with. This meant that the force of 120 oil can mortars had to be divided into three as there was no time to bring up another section of mortars from their base nearly 20 miles away to deal with the third strong point. The equipment was brought as far forward in daylight as it was possible to take a lorry without being detected. The section commanded by Livens had another 200 yd of open ground to cross via a track that was shelled every time anyone was seen on it, and the light would not permit this to be crossed until 6 p.m. It was made more complicated by the fact that the British bombardment was due to start at 8.30 p.m. To avoid short rounds and the inevitable German retaliatory bombardment, the carrying party had to have completed their job of taking the equipment as close to the German line as possible and returned before the bombardment started. Unfortunately, the party consisted of inexperienced men who had never been in the trenches before and they did not arrive at the dangerous section until exactly the moment the bombardment started. Despite seeing another, unconnected, party of four get blown to pieces, they somehow managed to get most things up to the proper place, although some equipment was left about 70 yd away and was very difficult to find in the dark.

Livens and his team had eighty mortars to set up and load, the most difficult part of which was splicing the eighty fuses into powder junction boxes that would allow the entire eighty to fire at once. They were installed almost side by side 'in the parados of an old piece of German communication trench' and were due to be fired at 12.30 p.m., H-hour of the attack. Everything was ready with 10 minutes to go, so everyone not needed for the firing was withdrawn to safety in readiness for the inevitable German counter-bombardment once the flashes from the mortars were seen. At 12.30 p.m., they were fired 'and the bursting cans made a fine splash of flame all over the German machine-gun posts'. The machine-guns never fired a shot. Within the next 3 minutes, a heavy barrage landed on the mortar position and it 'became very unpleasant'.

The next morning revealed that none of the mortars had escaped the barrage. More importantly, though, all the mortars had worked perfectly. Even when a mortar did burst, its bomb was actually propelled further than when the mortar remained intact. Later experiments showed that the bomb would invariably travel at least two-thirds of the maximum range when the mortar burst. To be on the safe side, Livens designed a fuse that would not arm until the bomb had travelled a minimum distance so that if one did fall short it would be blind.

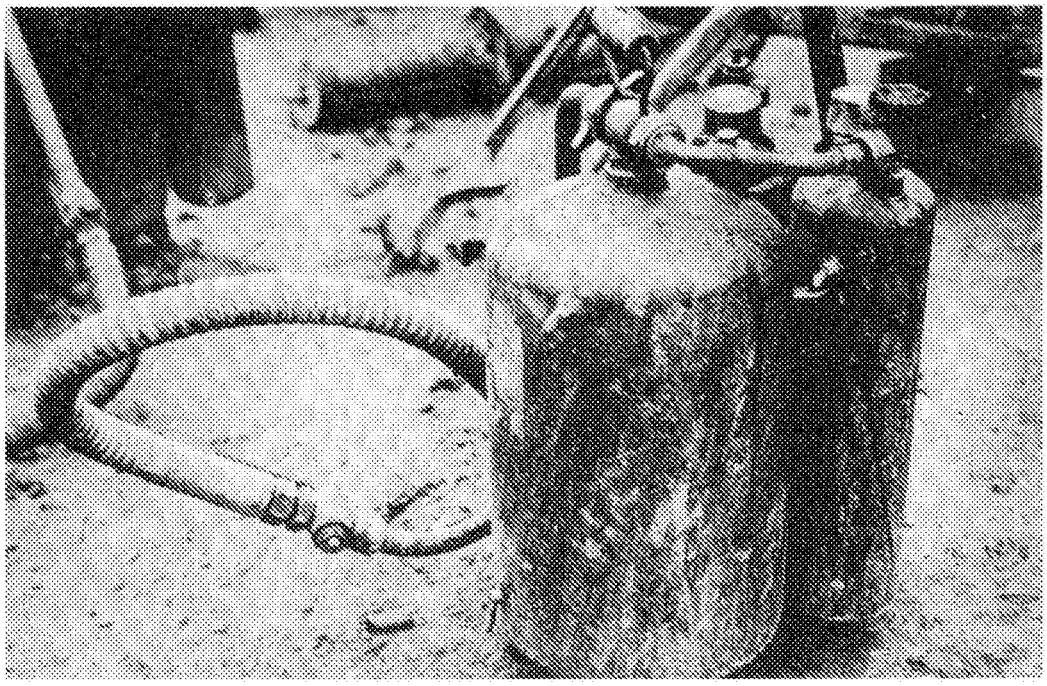
Not content with what he had achieved, Livens now proceeded to improve on the mortar and its bomb and these became the second pattern. By now, the terms being applied to these



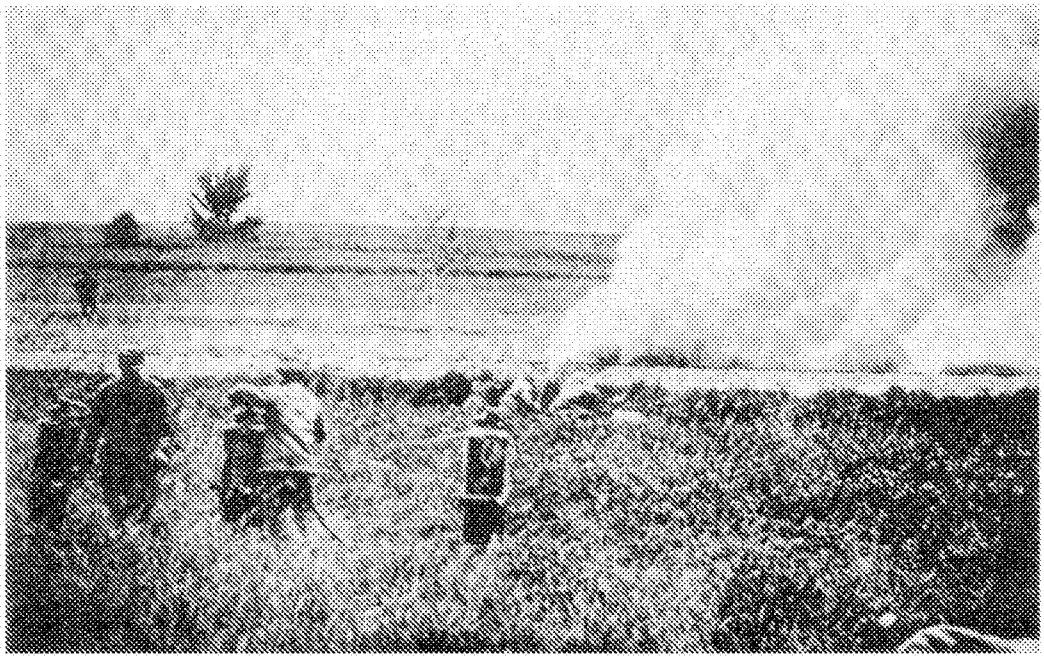
R. Fiedler's patent (30,161/10) for a portable flamethrower, dating from 1910.

improvised devices were 'oil drums' and 'portable cans for carrying oil up trenches' the latter shortly becoming 'portable cans'. For reasons of secrecy, these terms stuck, although the bomb soon became known as the Livens Drum. Even before the first operational use of the devices, Livens had sent sketches to Haig at the latter's request, copies going to the Trench Warfare Supply Department with a request for suitable drums. What arrived shortly afterwards was not quite what he had hoped for. The 'mortar' drums were 4 ft long but only 9.5 inches in diameter and had no tops, while the 'bomb' cans each had 'a separate compartment which, curiously enough just held a Mills grenade'. This was supposed to hold 'a priming charge of petrol'.

The second pattern of the mortar had a range of 350 yd with a bomb that weighed 60 lb when filled. The empty can weighed 18 lb so the ratio of filling weight to container weight was three to one. As Livens put it, this was 'extraordinarily economical'. The mortar and its bomb must have been the most cost-effective weapon of the war. The oil can mortar was also used to great effect during the attack on the Messines Ridge in June 1917. 'A lake of fire' was reported to have been created by 'a salvo of 100 Livens Incendiary Drums' and the term 'boiling oil' was used. Because of the success of the incendiary mortar the idea was



German Flammenwerfer, *late 1916.* (ILN)



French soldiers test a captured German flamethrower, September 1915. The cylinders are in the foreground while the hose operators are in the middle distance. (ILN)

extended to gas as a filling for the bombs rather than incendiaries. This subsequently became the Livens Projector, an incredibly powerful gas weapon and arguably the most effective of the war.

The Germans were the first to use gas and were the first to use flamethrowers, both in 1915. The history of the British response to both is inextricably intertwined with Livens, although the flame projectors (as flamethrowers were known) and gas dispensing apparatus were not at all alike. Nevertheless, through Livens the flame projector led via the oil can mortar to the Livens Projector. The history of gas warfare in the First World War may be short in terms of years but in terms of complexity it is a vast subject which can only be touched upon here. The focus here is on Livens who was a driving force in the development of both gas weapons and flame projectors.

The Germans first used flamethrowers against the British at Hooge at the end of July 1915 during the Second Battle of Ypres. Captain Hitchcock of the Leinsters described the 'liquid fire' attack as 'most demoralising' launched by 'a number of men carrying on their backs a tank similar to a potato-spraying device with a hose. From this jet issued forth a flame of liquid which was estimated could shoot some 30 to 50 yards.' Despite the surprise and the horror the flamethrower induced in the defenders, few men became casualties from burns. The flamethrower was operated by two men, one to carry the tanks, the other to aim the hose. The Leinsters were 'instructed to aim at those who carried the flame-spraying device, who made a good target'. The fuel tank of at least one unfortunate German carrying a flamethrower was hit during the attack and it 'blew up with a colossal burst'.

Before their operational use against the British, flamethrowers had been used against the French and on the Eastern Front. The French captured flamethrowing equipment which was

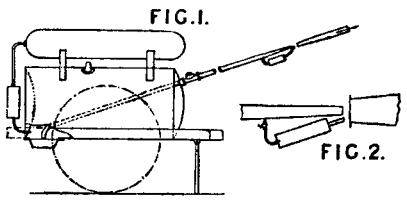
subsequently demonstrated to both the French and British troops. In March 1915 the Royal Welch Fusiliers attended such a demonstration. It was not an unqualified success since 'premature operation scorched some of the Staff, to the unconcealed delight of the infantry'. James Jack witnessed another demonstration in September 1916 and was of the opinion that such weapons were unsuitable for trench warfare, a view shared by many. He had a point. None of the flamethrowers used during the war was truly portable and the fuel, a mixture of heavy and light oils propelled by nitrogen or deoxygenated air, was not entirely safe especially if some oxygen was left in the air. It was not until the 1940s and the invention of a thickening agent called napalm – a derivative of naphthenic acid and palmitic acid (hence the name) that turned the liquid fuel into a gel which was much easier to project with less chance of the fuel burning back to the projector – that flamethrowers became really effective. Moreover, the unthickened oils used in the First World War had a tendency to burn up before reaching the target so that very little fuel actually made contact with it. Napalm overcame these problems.

The German use of flamethrowers at Hooge demanded an immediate response, except that the British had no similar devices. An experimental programme was quickly started to devise long-range as well portable flamethrowers that one man could carry and operate. Private enterprise was already ahead of the game. Joseph Menchen, an American with experience of industrial fuel burners, had approached Colonel Jackson in February 1915, claiming that he could make a flamethrower despite having no experience of such things – he believed that there was probably very little difference between burners and flamethrowers. Jackson, keen to encourage new lines of development, asked him to design two types, a short-range model and a long-range one.

The short-range portable model was ready for trials in April and although it seems to have performed well with a respectable, if not outstanding, range of about 20 yd, the device was rejected. The long-range model consisted of four cylindrical fuel tanks joined in series to a single discharge tube with a nozzle along with an equal number of compressed air cylinders, each cylinder being fed by an air bottle. Although this trial model had everything joined in series, Menchen thought that it would work equally well if they were joined in parallel or even radially. The fuel and the propelling gas were released with valves that were arranged to ensure that the fuel was released before the gas. It had a range of about 100 yd but was rather too complicated to be of practical value in the trenches, of which Menchen, unlike Livens, had no experience. Menchen, like so many inventors, had sufficient faith in his devices to believe that it was worth his while filing four patent applications in late 1915. He was subsequently granted three patents, two of the applications having been combined at a later date (14,715/15 was concerned with the flamethrower as a whole, 14,716/15 was concerned with the valve system, and 16,062/15 was concerned with the nozzle and ignition system).

Meanwhile, a French company, Hersent, had also developed a flamethrower which was the subject of two UK patents. The application filed on 27 March 1915, concerned with the flamethrower unit, became 7,524/15 while the second filed on 4 November related to the ignition system and was granted as 15,581/15. The Hersent device was simpler than Menchen's. Captain Vincent, one of the team developing British flamethrowers for the Trench Warfare Department, borrowed some the features of the Hersent device, and assisted by Captain Hay came up with a 'knapsack' model that had a range of about 35 yd. Vincent demonstrated it at Wembley on 15 December 1915. The trial went well but the device only had a fuel capacity of 6.5 gallons which allowed just 17–18 seconds of flame. The apparatus was no lightweight at 80–85 lb but fortunately for the operator it was well distributed.

There were, however, grave doubts about the usefulness of a one-man flamethrower. GHQ did not believe that it was suitable for the conditions in France. It was suggested that if the knapsack flamethrower was adopted, the fuel would have to be sprayed on the ground, then ignited with a firework instead of projecting fuel and igniting it at the nozzle. This rather odd and unrealistic idea came about because of a genuine fear that the operator might be sniped by the enemy so that the flame could be turned on friendly troops, although how spraying the fuel on the ground first avoided getting sniped is rather obscure. Strangely, the idea that it could be used to clear pillboxes or blockhouses, as flamethrowers were used in the Second World War, never seems to have crossed anyone's mind (although in fairness these did not become widespread until 1917). The only use that could be suggested for the device was in street fighting, a somewhat absurd notion at that time since there was no prospect whatsoever of street fighting occurring in the near future.

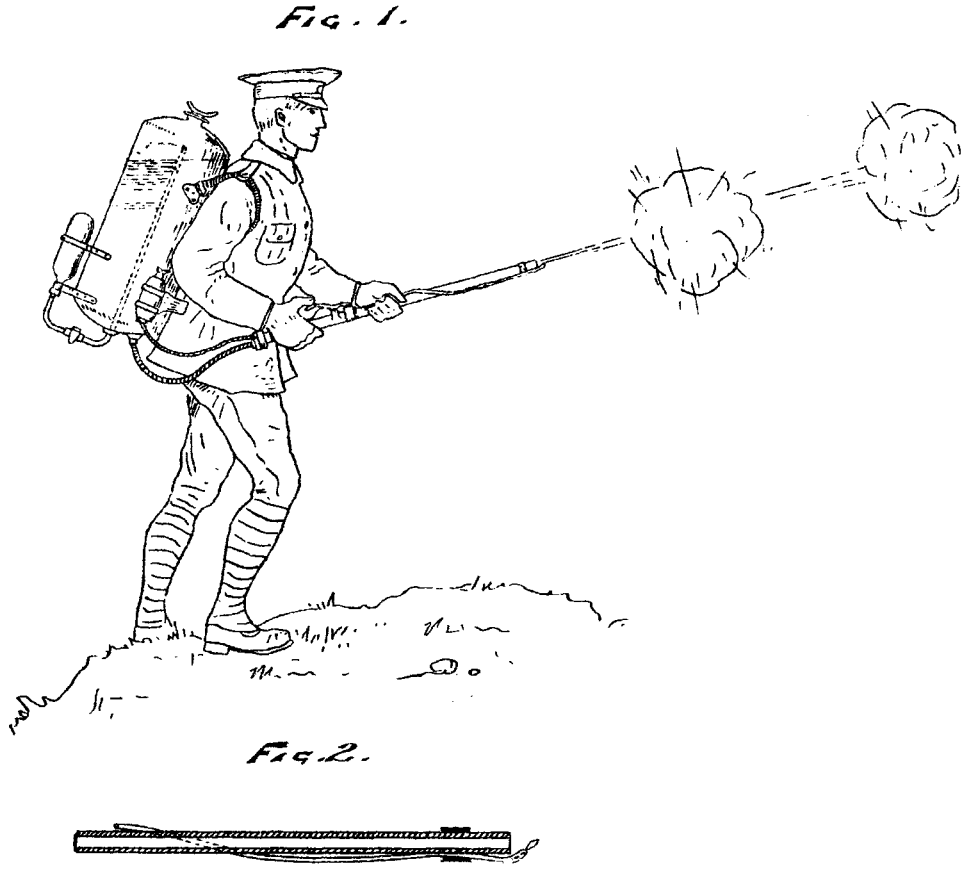


Drawing from one of Hersent's patents (7,524/15) for a flamethrower mounted on a truck. Fig. 2 shows the ignition system for injecting a more flammable liquid into the stream which is mixed in the tube on the right.

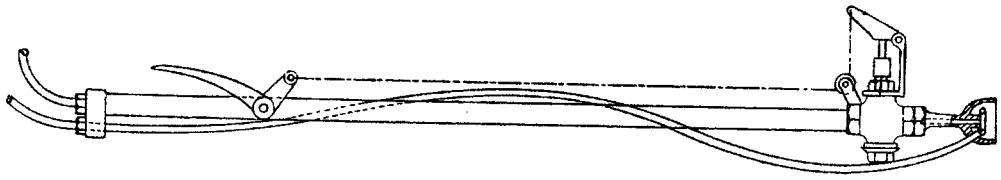
None of the one-man flamethrowers that were trialled during the war, mostly during 1915 and 1916, was ever really considered suitable for trench warfare. All were rejected for Army use although some found their way to France only to be dismissed out of hand by GHQ. Only the Navy showed a real interest and used Hay one-man models during the 1918 raid on Zeebrugge.

The flamethrower trials held at Wembley on 15 December also saw the demonstration of two other types that could be described as medium and heavy, the former having been designed by Vincent. The medium was a semi-portable device with a range of between 40 yd and 60 yd and a crew of two, while the heavy or battery model had a crew of eight. During the course of the trial of the semi-portable flame projector, one of the compressed air cylinders burst and the operator was severely burned, along with Vincent. The cause of the accident was put down to a rivet shearing and the manufacturer of the Duralumin cylinder, Vickers, was blamed. However, this does not appear to have influenced any decision about the viability of such equipment at the Front. At 230 lb, the equipment was too heavy to be carried and had to be transported on a special truck. The tanks had a capacity of 15 gallons which allowed a flame time of only 20 seconds. Despite the accident, it was considered to be simple and safe and was viewed more favourably than Menchen's device.

The battery model comprised four units, each with four 20-gallon fuel cylinders each of which could produce 11 seconds of flame. If two of the units worked together the flame time was 23 seconds and if all four were used in unison a discharge of 45–50 seconds duration could be achieved. The equipment was provided with a quick shut-off valve which could be used to throw a continuous succession of balls of flame 80–85 yd for 3–3.5 minutes with an average of four balls per cylinder or sixteen for the battery as a whole. Because of the length of the jet (and because this was unthickened fuel) the wind direction and strength made a considerable difference to the range as well as to the accuracy.

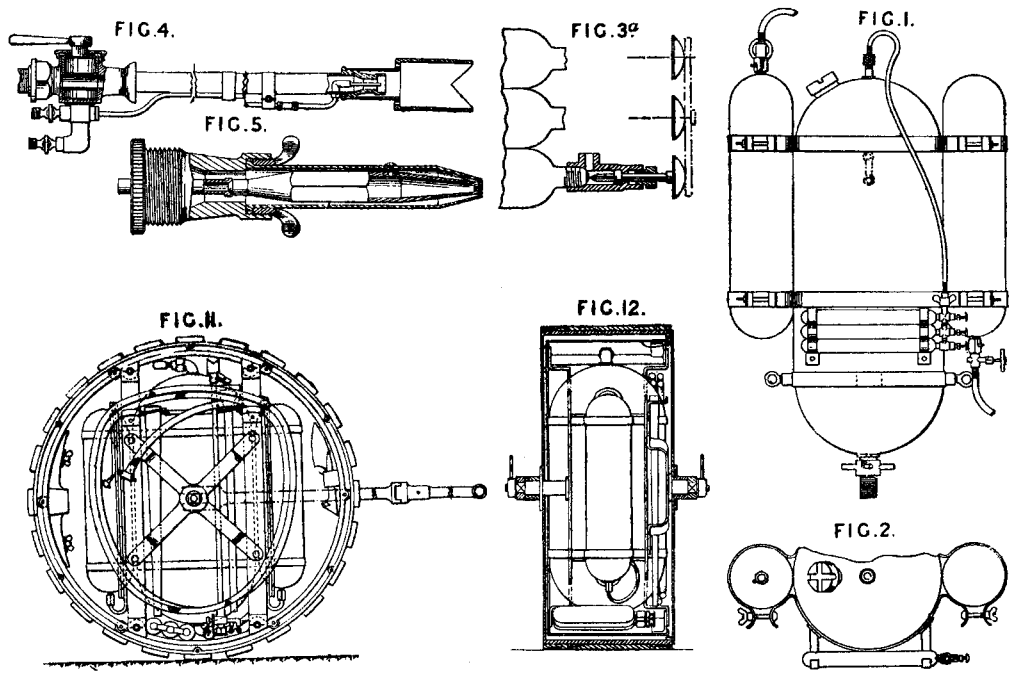


William Hall's portable flamethrower (UK patent 15,288/15). Note the lever for projecting 'puffs of flame' rather than a continuous stream. The specification stated that in a continuous stream 90 per cent of the fuel is wasted.



Drawing of the lever attached to the nozzle valve from Hall's patent.

Having successfully fired the projector to a more than respectable distance, it was decided to try igniting the stream of liquid after it had left the nozzle to see if the range could be extended. It was recognized that the range was affected by the quantity of fuel that was burned up before reaching the target. To this end, the jet of fuel was ignited after the projector streamed instead of at the nozzle but the results were very disappointing. A meagre 40 yd was all that could be achieved by this method so it was abandoned.



P.H. Lawrence's flamethrower from 1915. It has a complex nozzle system for mixing oxygen and chlorine gases (stored in the smaller side cylinders in fig. 1) to ignite the fuel which was 6 parts turpentine, 1 part carbon bisulphide and 2 parts phosphorus. It can be carried on the back or mounted in a roller as shown in fig. 11 'for rolling down a trench'. Although assigned a number (17,696), no patent was granted because the sealing fee was not paid.

What was needed was thickened fuel. Had anyone realized it, there was a thickener readily available – natural rubber. The ability of natural rubber to thicken fuel into a gel was not generally known at the time and, in any case, natural rubber was a strategic material already earmarked for a variety of essential war uses, not the least being vehicle tyres and obturator rings in artillery (these went inside the breech and sealed it when the propellant was fired, ensuring no gas leakage). The use of rubber would have transformed flamethrowers from dangerous Heath Robinson contraptions to truly effective weapons.

The battery model was a much more formidable weapon than either the semi-portable or knapsack models but it had one considerable disadvantage – its size. The battery weighed 2,500 lb and was 16.5 ft long and 4 ft 6 in high. It would be neither easy to take into the front line nor easy to conceal once it was there, yet it was a similar device that Livens took to France with the intention of using it during the Somme battles. Livens did not like the two-man flamethrower demonstrated at Wembley on 15 December, considering it to be badly designed and unsuitable for the trenches. He set about designing an alternative better suited to trench conditions. He had already conducted his own experiments with a one-man device of his own invention. Livens enlisted the help of his father at the firm of Rushton Proctor in Lincoln and between them they designed and built two types including a large battery model.

It took Livens six months. There seems to have been a permanent difference of opinion between the researchers, the Army Council and GHQ about the usefulness of the devices. And although Livens was dismissive of Vincent's two-man device, the Army Council was still considering it and had ordered several sets, only to change its mind later. By June both types designed by Livens and his father were more or less ready. The Large Gallery flamethrower was a monster which bore an uncanny resemblance to a mechanical sea serpent with a long neck that curved up to a small head from which the fire would belch, fuel tank humps and a tail of gas cylinders. The idea was to bury it in an underground galley close to the German front line prior to an attack – no mean accomplishment considering its size – and raise its head through the covering earth to spray fire at the enemy. As Livens wrote later

> the only way to bring the business-end of the weapon near enough for the enemy to be in range was to install the apparatus in a mine-shaft, going forward from our front line towards the enemy, but mine-shafts require many days, if not weeks, to dig, and five yards a day is about the maximum progress possible on a quiet front in suitable ground. Therefore, while the Flammenwerfer was well suited to the purpose [for] which it was designed, the commencing phase of an offensive from an old established front where mining had gone on for many months, it was of little value during the subsequent fighting in the enemy's old lines to enlarge the initial gain.

The device consisted of seven sections of 9 in diameter pipe joined in series with a discharge nozzle on the end of a narrow pipe at the 'head' and twelve gas cylinders via a reservoir tank at the 'tail'. The 'head' could be raised hydraulically and was armoured so that it cut through the covering earth of the galley. The 9 in pipe was both tank and discharge pipe as it contained the first shot of fuel which was propelled up the pipe by the gas acting on a piston. The fuel was ignited at the nozzle by acetylene which ignited spontaneously in air. The acetylene was generated in situ by dripping water on to calcium carbide. Two further shots were provided by a series of five tanks above and connected to the 9 in tube. In all, the device contained 250 gallons of fuel.

The smaller flamethrower was a two-man device that contained 12 gallons of fuel in a single tank discharged by gas from another tank. It was not meant to be carried in action, however, and only had a range of 35 yd. In June 1916 six gallery models and twenty-four semi-portable models, both of Livens's design, were sent out to France to be set up for use in the forthcoming Somme offensive. Only four of the large models were prepared for action and only two of them were used successfully, the other two being lost through the effects of shellfire before they could be brought into action. On 1 July, the first day of the Battle of the Somme, the two Livens flamethrowers seared the German trenches a quarter of an hour before H-hour. About forty Germans were killed and many more terrified, but it is doubtful whether this made a significant difference to anything. The two-man flamethrowers saw action twice during July and again in September when the large model also saw further action. Apart from a couple of flames in 1917 and the Zeebrugge raid in 1918 that was the only use of British flamethrowers. Their contribution had been negligible.

There seems to have been an almost perpetual shortage of fuel for the flamethrowers and requests were regularly submitted to the War Office. On 19 June 1916, even before Livens's devices had been tried on the Somme, the Army Council stated that 'Flame Projectors already demanded will be used whenever an opportunity offers until they

become unserviceable; they will not, however, be replaced'. Flamethrowers were not regarded as effective enough to warrant more equipment being sent out to France and Haig did not want them in any case. Experimentation was to halt forthwith.

The far simpler oil can mortar, which had arisen from the need to find an alternative way to attack the German trenches with incendiaries, was a much more effective weapon than any of the flamethrowers. The success of these mortars led to the idea that the mortars could be used to throw gas bombs at the Germans in the same manner. When the Germans first released chlorine from 5,000 cylinders at Ypres in April 1915, against Algerian troops of the French Army, the British Army wanted a response to this new threat. By September the Army was ready to release a gas cloud of its own against the Germans at the Battle of Loos. Although these and later uses of gas clouds proved to have a limited effect against an unprepared enemy, it was realized that there were simply too many variables to guarantee success. These were mostly connected with the weather (for example, air temperature, wind speed and direction) but were also related to how far the gas had to travel and the density of cylinders in the release area. There were instances where a simple change in wind direction completely threw all planning and timetables into disarray.

British portable flamethrower on board HMS Vindictive *following the Zeebrugge raid in 1918.* (ILN)

Livens knew that if gas was to be effective it had to be delivered in higher densities than could be achieved with gas clouds. In addition, greater control over the gas was essential. Although both artillery shells and mortar bombs were adapted to carry gas, the effect was still limited and measures could be taken by the enemy to minimize the number of casualties. Shells and bombs could neither carry a big enough payload nor produce a high concentration in one place. It occurred to Livens that by adapting his oil can mortar bombs to carry gas instead of flammable liquid it might be possible to lay down a very dense, localized cloud of gas, especially if a large number of mortars were fired simultaneously. He conducted some experiments which showed that the idea was not only sound but potentially even more destructive than his cans of petrol.

The gas projector was first used operationally in the capture of Thiepval in September 1916, followed by a repeat performance during the capture of Beaumont Hamel in November. These were not full-scale projector operations, merely trials to prove the concept. The proof was very convincing and General Sir Hubert Gough in command of the Fifth Army and his Chief of Staff General Neill Malcolm gave Livens all the cooperation he needed to develop the weapon in the field while keeping it secret from the Germans. Both recognized the

potential of the weapon and arranged for the projector to be used only against positions that would be immediately taken by the infantry. This ensured that no information about the new weapon could be passed back to the German rear. Indeed, so successful were these precautions that the Germans were completely in the dark about the projector until well into 1917 and even then they did not know how the weapon worked.

Some of the reports that the Germans did manage to write were captured before they could be sent back to the German divisional staff. The reports assumed the attacks to be gas clouds released in the usual way but of far higher density. During the Thiepval attack about 1,100 lb of gas was fired at a frontage of only 80 yd and this formed a 'gas lake' that flooded the cellars of the ruined Thiepval Château, occupied by the German commander of the Thiepval garrison. He, along with at least 130 other German soldiers, were killed by the gas. At Serre, 200 Germans were killed and the German commander reported that the attack was 'of a new kind, of great intensity, delivered without warning' and was desperate to know what he should do against a future attack. He received an unhelpful reply 'to take the necessary precautions' but died before he could do anything.

On the day after the gas attack on Beaumont Hamel, the infantry took what remained of the village. Livens discovered a deep German dugout untouched by 'our heaviest shelling with twelve inch howitzers', with fifteen Germans, five rats and a cat all dead. They had died in the act of trying to escape and the evidence suggested that it had happened within a matter of a few seconds. This was not because the gas was any more lethal but because of its concentration.

> This dug-out was in the track of a cloud containing nearly a ton of gas, and the number of seconds in which these men were killed could be gauged almost exactly, because the three furthest from the entrance down which the gas had come, had had time to put their gas-masks on before they died, the fourth man had his mask half on, and the fifth had it to his face, the sixth out of the box, the seventh had opened the box, and completing the series, the eight[h] had his hand on the lid, while those in front were killed so quickly they had not had time even to think about their masks.

Livens likened the scene to 'a cinematographic series of photographs of German gas-mask drill'.

The well-trained German soldier could don his gas mask in less than 6 seconds. In all likelihood, the concentration of gas was so high that the normal gas mask was ineffective. What made the scene all the more remarkable was the fact that the centre of the beaten zone (the area into which all the drums were fired) was some 300 yd away and the nearest bomb or 'drum' had landed 280 yd from the entrance. The main target, the deep artillery-proof dugouts used by the German garrison, revealed an even more startling picture. When these were examined, they were found to contain approximately 300 dead, all of whom had been killed by the gas. This was the reason for the comparatively light casualties suffered by the infantry when it crossed No Man's Land to take the German positions. A similar attack on the nearby Y Ravine was equally successful. This was an astonishing vindication of the projector and gas drum projectile.

Having now established the effectiveness of the weapon (which, unlike the first oil can mortars, were made by Hartley & Sugden), Livens proceeded to improve on it. The acetylene welds of the early drums which contained the gas tended to become porous due to corrosion caused by moisture and chlorine (chlorine gas is made up of diatomic molecules of chlorine, hence the chemical formula Cl_2, but some chlorine atoms remain unattached and these readily

dissolve in water to form hydrochloric acid). This would not have been a problem but for the fact that the drums were filled with the gas in the field and had to be stored until required for use. The filled drums had no fuse and relied on splitting open on impact. Thus, the drums were not inherently strong and there was always the danger of leaks or splits from rough handling.

Eventually, fire welding of 3/16 in sheet was shown to be the best way to make gas-tight drums and these, like the first gas drums, were made by Stewart & Lloyd at their Coatbridge factory near Glasgow, as well as at their Birmingham factory. By the end of the war, 430,000 had been made. It is evident that the French also used the Livens Projector with drums of the same pattern and the Italians proposed to do likewise.

The projectors only had a range of 350 yd which, as the battles of the Somme developed, was quickly recognized as too short. Livens needed a more robust tube from which to project the gas drums, and discovering that 'a certain quantity of waste Mannesmann tubing in odd lengths' was left over from work done for the Admiralty he decided to experiment with this. (The Mannesmann process made seamless tubing from a metal bar with two eccentrically mounted rollers. The rollers simultaneously rotated the bar and forced it over a mandrel.) Livens selected 8 in diameter tubing which had to be at least 3 ft long to maintain a minimum length to calibre ratio of four to one which earlier experiments had shown to be essential for the 'parallel portion' of the bore if the projector was to fire a drum to a good range. Anything less than this caused the range to drop off drastically. The maximum weight of the projector had to be kept to 100 lb as this had been determined as the maximum load that could be carried without special equipment. The length and weight determined the thickness of the walls of the projector which were 3/8 in thick. A black powder charge gave a range of 1,300 yd and was electrically ignited, the wires passing down the tube from the muzzle to the charge.

By now, the First, Third, Fourth and Fifth Armies were keen to get hold of as many of the projectors as possible. This required coordination with GHQ and General Thuillier as Director of Gas Services arranged with the Ministry of Munitions and the War Office to have as many projectors as possible manufactured in time for the forthcoming offensive in the spring of 1917. Livens attended the conference in the UK and remained in England to help deal with the technical problems that needed to be resolved. It was during this time that he perfected the drums. The projector had been transformed from an improvised device into a 'proper' weapon system. Throughout the whole process, Livens had not worked alone and he owed a debt of gratitude to many officers, as well as to his father, which he was only too willing to acknowledge. In fact, he made it plain that the credit for the invention should be shared equally between himself and his father. Without the support of the Director of the Trench Warfare Supply Department, the weapons would never have reached France in the numbers needed to make the impact they were about to make.

The Livens Projector was, of course, a mortar and the Livens Drum was a mortar bomb. The reason the projector was not called a mortar was logistical rather than secrecy although the term did help to obscure what the projector was. By avoiding calling the weapon a mortar meant that it was not classified as a gun. Guns came under the auspices of the Ordnance Board which would have been responsible for supplying the weapon. This would have inevitably slowed the supply process because of all the other guns which the Ordnance Board had to deal with. But if the weapon was called something else that did not suggest 'gun', it could be supplied to France by other means, i.e. the Trench Warfare Supply Department. The significance of all this was the speed with which Livens wanted the weapons supplied so that they could be used in the numbers necessary for them to be truly effective.

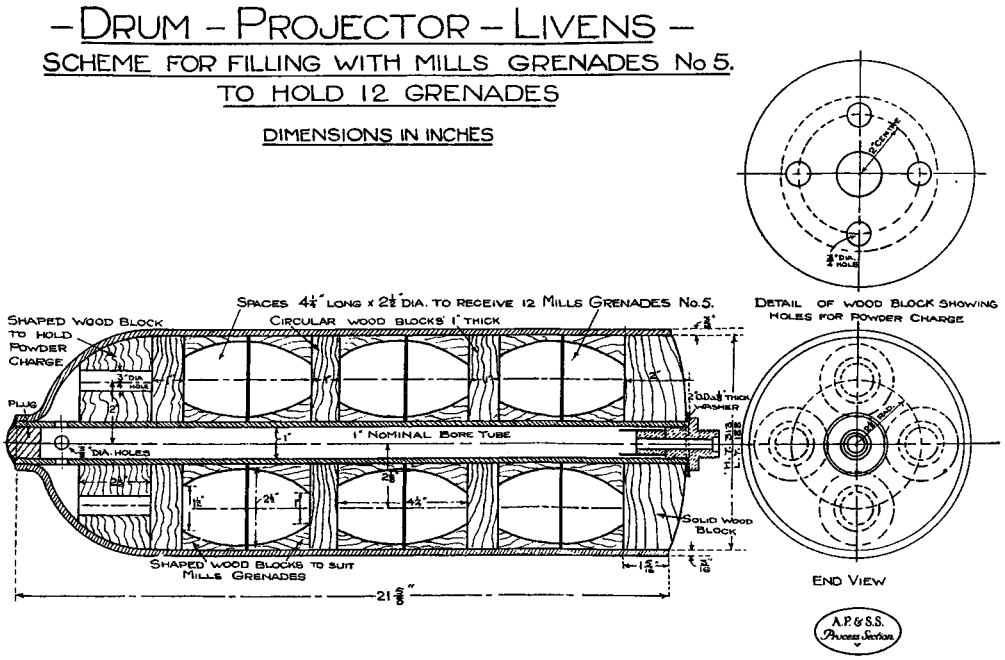
Vimy Ridge in April 1917 was the debut of the new projector. Half an hour after dawn broke, 2,000 were set up along a crescent of front above Arras and opposite Vimy Ridge. From an aircraft, Livens watched the drums burst on the German lines and the gas cloud drift over their positions. It travelled for more than 4 miles. The Germans believed that the 'Gas Minnen' had been propelled pneumatically or by catapults of prodigious proportions because they had heard nothing before the drums arrived. As Livens wrote later 'A catapult which would throw a 65 lb bomb well over a kilometre would have surprised even Archimedes'. The absence of noise was rather puzzling, however, since these projectors were far from quiet and 2,000 of them made a tremendous noise that could be heard 40 miles away over the noise of the artillery bombardment. Livens concluded that the noise was not associated with the gas drums partly because those on the receiving end tended to be dead so that there was little opportunity to communicate information with the rear. Moreover, the considerable flash of 2,000 projectors being fired simultaneously could have been mistaken for a mine being exploded. But this was pure speculation. The German casualties during the assault on Vimy Ridge were immense.

Even before Vimy Ridge, Livens had been experimenting with alternative propellants to black powder to increase the range of the projector. Newton, now a colonel and Deputy Controller of the Trench Warfare Department, provided invaluable assistance as did Colonel A.W. Crossley, Commandant of the Gas Warfare Experimental Ground at Porton Down. With the further assistance of Captain H. Goodwin, flake cordite was chosen as the propellant. However, this type of propellant needed an initial pressure of at least 1 ton per square inch for it to be burned properly. The space between the wall of the projector and the drum had to be reduced to achieve this level. It had always been a requirement that neither the tube nor the drum should be machined in any way as this would slow down production. The tolerances were consequently low. Therefore, Livens had to find a way of closing the gap that did not involve machining. He came up with a steel gas check fixed to the charge box.

The first trial with the cordite and gas check was held after Livens's return to England after Vimy Ridge. It was successful, the range being increased to 1,800 yd. He believed that this increase 'more than doubled the value of the weapon'. Later experiments with bombs of stronger construction showed that the range could be extended to 2,500 yd but these were not ready for use before the end of the war. With the weaker drums, the range could not be extended beyond 1,800 yd as the higher cordite charges needed to achieve the longer ranges tended to make the drums bulge which caused the projectors to burst.

In the autumn of 1917, Livens became a member of the Trench Warfare Committee. The committee took on the job of further development of the projector and several variations on the tube were developed to overcome the shortage of Mannesmann tubing. The most important of these were the wire-wound projectors and the forged projectors. The wire-wound projector was, in fact, a composite of lap-welded, ¼ in steel tubing fitted with a mild steel 'thimble' to strengthen the breech end and wound with 'a double layer of flat gun steel wire' which had a tensile strength of 90–100 tons per square inch. The Mannesmann projectors had a tensile strength of 40–50 tons per square inch whereas the ¼ in steel tubing only had a strength of 28–32 tons per square inch, but when it was wire-wound the finished projector was as strong as the Mannesmann projector and only a little heavier.

However, there were difficulties with wire-wound projectors because the gun wire was brittle and had to be protected against damage. There was also the problem of how to securely tie off the end of the wire. Moreover, the finished tube behaved differently from Mannesmann projectors. A 3/16 in radial bulge rippled up the lap-welded tube as the gas check travelled up it although it regained its shape afterwards. Nevertheless, this was a potential


– DRUM – PROJECTOR – LIVENS –
SCHEME FOR FILLING WITH MILLS GRENADES No 5.
TO HOLD 12 GRENADES
DIMENSIONS IN INCHES
SPACES 4¼" LONG x 2½" DIA. TO RECEIVE 12 MILLS GRENADES No.5.
CIRCULAR WOOD BLOCKS 1" THICK
SHAPED WOOD BLOCK TO HOLD POWDER CHARGE
PLUG
1" NOMINAL BORE TUBE
SOLID WOOD BLOCK
SHAPED WOOD BLOCKS TO SUIT MILLS GRENADES
DETAIL OF WOOD BLOCK SHOWING HOLES FOR POWDER CHARGE
END VIEW
A.P.&S.S. Process Section

The Livens Projector. This shows an experimental method of launching twelve Mills grenades from the projector, illustrated in 'Notes on Inventions and New Stores No. 2', July–August 1917. (MUN 4/3590)

hazard as the wire and the tube were of different tensile strengths and permanent ripples could be left in the tube rendering it useless. Yet, such objections were regarded as unimportant since there was little in the way of an alternative; they just had to live with it. Large numbers of the wire-wound projectors saw action in France.

The forged projector was also produced in large numbers, several thousand being used in action. A billet of steel was forged on a hydraulic shell-press exerting pressure of 1,500 tons per square inch, followed by two drawing press operations. The inside was left slightly tapered towards the base by the process. The tube was subsequently cleaned and made uniform with an appropriate tool. The end was trimmed and the excess metal was turned off the exterior to reduce thickness and weight. That was all there was to it. It was an expensive process but on the plus side the projector was superior to any other with a longer range, the slight taper seeming to be a distinct advantage.

The projector was so effective that no one was surprised when the Germans began to make copies to return the favour. There were two types and although well made they were not a patch on the British originals. More seriously for the Germans, they failed to grasp the importance of using the projectors *en masse* to achieve the best results. One of the types had a rifled bore which was reputed to have a very long range but when tested by Livens he could only achieve 2,800 yd with it. It was also expensive to make and could not have been produced in large quantities because of its complexity. By the end of the war, the Allies had manufactured more than 150,000 projectors and more would have been used had they been available.

Livens declined to speculate on what might have been achieved had more projectors been available along with the necessary gas-filled bombs but he cited an operation where 600 projectors had been used to indicate the 'devastating nature' of the weapon. The operation took place near Passchendaele in October 1917. One night, two Special Companies of Royal Engineers fired 600 projectors in two groups. The German 80th and 81st Reserve Infantry Regiments, at whom the projectors were aimed, were nearly annihilated and another regiment suffered heavy casualties. In all, 2,500 Germans were killed in the operation. One reason for the high death toll was that the Germans had been caught in the middle of a relief but that did nothing to detract from the power of the weapon.

Besides the British and the French, the Americans also used the Livens Projector. The Italians had planned to use it but the war ended before they got the chance. The weapon certainly terrified the Germans, not just because of its devastating effects, but because they never knew when an attack would occur. Many of the gas attacks carried out by the British after Vimy Ridge in 1917 were conducted with Livens Projectors. The German Army suffered such high casualties from these attacks that its soldiers were forbidden to talk about the effects.